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Use of two plants to remove pollutants in wastewater in constructed wetlands in southern Iraq

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ABSTRACT

Industrialization, urbanization and population are the most important reasons for pollution in Iraq, these factors have decreased the quality of water resources. Evaluating the treatment of polluted water (sewage) in nontraditional ways and assessing consumption in the agriculture sector are the main purposes of this study. Two Plants were used in the current study *Schoenoplectus litoralis* and *Hordeum vulgare* to remove heavy metals and nutrients, making this technique effective in pollution control.

Samples were collected from the storage terminal of the wastewater station in Al-Nassiriya (Indian station), Physicochemical analysis of both sewage and tap water was performed for following parameters; Ion Hydrogen (pH), electrical conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solid (TSS), Carbon Dioxide CO_2, Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Sodium (Na^+), total hardness, alkalinity, Chloride (Cl^-), sulphates (SO_4^{2-}), phosphates (PO_4^{3-}), nitrates (NO_3^-, Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD_5) were evaluated. Moreover, four trace metals [Lead (Pb^{+2}), Nickel (Ni^{+2}), Copper (Cu^{+2}) and Cadmium (Cd^{+2})] and the sodium adsorption ratio (SAR) were evaluated. The plants varied in their responses to metals. This study revealed that plants have a high heavy metal removal capacity.

Introduction

Protection and management of ecosystem resources are the main objectives of sustainability. Because of the huge progress in industry and technology, wastewater is the chief pollution issue in ecosystems. Collecting and treating wastewater has been a recent environmental concern around the world. Many scientific methods have been used to address this problem. The purpose of such methods is to reduce the cost of treatment and to utilize special materials that are environmentally friendly, such as aquatic macrophytes (*Phragmites* sp.). Wastewater treatment by using aquatic plants could be one of the most powerful methods.

The microbiota plays a role in removing organic matter and nutrients (Wetzel, 2000; Tanner, 2000), and many studies have shown that plants can influence nutrient removal (Tanner 2000; Drizo et al., 1996). Plants have a vital role in ecology; for example, plants convert solar energy to bioenergy and produce food for animals and humans. Furthermore, they can clean the environment. Plants can play a major role in heavy metal remediation. Phytoremediation is the use of green plants to eliminate or reduce pollutants in the environment. In contrast to expensive and complex methods, wetland engineering has a low cost and represents clean technology for wastewater treatment (Chong-Bang et al., 2010; Yongjun et al., 2010). The use of wetlands for purification has many advantages; for example, there is no need for high-cost buildings (Almuktar et al., 2018).

In Iraq, many studies have focused on environmental sustainability, particularly the interaction between heavy metals and plants (Maktoof and Al-Khafaji, 2015; Khair Allah, 2017). On the other hand, a few studies have been conducted on the use of constructed wetlands for waste treatment (Kazam, 2016; Al-Enazi, 2014). Bioremediation of heavy metals has been studied by many researchers around the world (Xia and Chen, 1997; Wu et al., 2000; Jiang et al., 2000; Abou-Elela et al., 2016).

The aim of the present work is to evaluate the remediation of wastewater by using constructed wetlands containing two plants: *Schoenoplectus litoralis* and *Hordeum vulgare*.

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Materials and methods

The locations of sample collection

All samples were taken from the collection chamber at the Al-Hindia plant (used for wastewater treatment in Al-Nassiriya city), which is located near Al-Zarae on the road that leads to Ur city/Nassiriya city, southern Iraq. The plant treats the wastewater that comes from city centre through the line that contains the wastewater produced by houses, restaurants and industry. These plants collect wastewater, which includes sewage and rainwater. The samples were taken during autumn in 2015 to conduct chemical and physical tests for the wastewater before and after filtration. The samples were kept in plastic containers (polyethylene), and smaller containers (250 ml) were used to collect samples to measure the biological oxygen demand (BOD_5). The samples were transferred to the laboratory Advanced Pollution and Ecology at the College of Science/Thi-Qar University.

Physicochemical analysis before filtration

The major physicochemical parameters include the following: pH and electrical conductivity, which were measured with a multi-parameter meter, model WTW 2FA 310. The other parameters were determined by the following methods: total dissolved solids, dried at 180 °C [Method 2540 C] and total suspended solids, dried at 103–105 °C [Method 2540 D], the concentrations of magnesium [by calculation 3500-Mg B], calcium [EDTA titrimetric method 3500 B], chloride [Titrimetric method 4500 Cl B], alkalinity [Titrimetric method 2320 B], biological oxygen demand BOD5 [5210 B], chemical oxygen demand COD [5220 C], total hardness [EDTA Titrimetric method 2340 C], and carbon dioxide [4500 CO2 C], nitrate [Colorimetric method 4500-NO3-F], sulphide [Iodometric Method 4500-F] and phosphorus content [ascorbic acid Method4500-P E]. Analyses of heavy metals and sodium contents were conducted after acid digestion (nitric acid/hydraulic acid digestion). Atomic Absorption Spectrophotometry [model AAS-6300, Shimadzu, Japan] was used to analyze the four heavy metals Lead [(Pb^{2+}), Nickel (Ni^{2+}), Copper (Cu^{2+}) and Cadmium (Cd^{2+})] according to (APHA, WWA, WEF, 2005) and sodium was analysed by Flame Photometer [Jenway 500 701, Canada] according to (IS 3025-45, 1993) [method 3025 (Part 45)] and sodium adsorption ratio SAR was calculated the following formula:

$$SAR = Na^{+}/[\surd(\ Ca^{2+} + Mg^{2+})/2]$$

Sample collection

S. litoralis samples were collected from Al Gharraf River in Thi-qar province, as this region was distinguished by the abundance of these aquatic plants, and straw of *H. vulgare* samples were collected farms near Al-Gharraf River in Thi-Qar Governorate. Then the *S. Litoralis* plants were washed with water to get rid of the suspended matter and the clay present with the roots and stored in plastic bags until they reached to the treatment system for transplantation.

Phytoremediation filter preparation

For the preparation of boxes that used for the incubation of *S. litoralis*, the boxes have 120 × 100 × 65 cm dimensions (Fig. 1) at the bottom there is a layer of 30 cm was used for an implant of the plants, this layer was divided into three sublayers; the first layer of the bottom was large gravel with a depth of 10 cm and a size of gravel between 2 and 1 cm (Fig. 2), and The second layer (10 cm depth) also contain gravel with size ranged between 0.5 and 1.5 cm, and The third layer (10 cm depth) consisted of a mixture of gravel and agricultural sand with a ratio of 3:1 (sand: gravel). The difference of gravel sizes is of great importance in the treatment tubes. If the gravel and sand layers are very rough, then the pollutants in the wastewater will leach through them very quickly without giving sufficient time for treatment by aquatic plants, and these sizes and layers differ according to differences of size and area of the tube. These tubes are considered good media for the growth of aquatic plants and the multiple spaces contribute to reaching a good ventilation system. 20 plants from both *S. litoralis* were implanted in each box. The lengths of plants ranged between 0.5 and 1.5 m (Fig. 3).

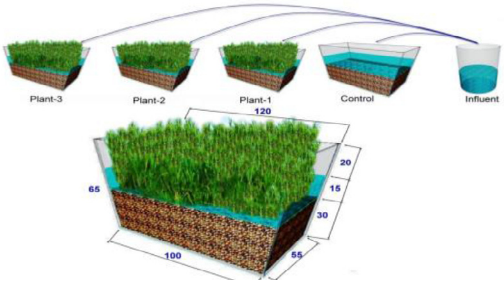

Fig. 1. 3Dmax for Phytoremediation processes.

Fig. 2. The floor used in the treatment system.

Sand and straw of H. vulgare filters preparation

Straw *of H. vulgare* and sand filters tubes that were 150 cm in length and 10 cm in diameter were used, these tubes had open ends that were covered with a special closing material, and a hole

Fig. 3. Plant treatment boxes.

was made in the centre of the bottom, which contained a valve that controlled the release of water. All filters are cleaning from dirt by using tap water several times followed by distilled water.

The sand filters tubes filled with gravel and divided to three layers, down layer were made from coarse gravel with a depth of 10 cm for each one (size of gravel ranged between 2 and 1 cm), the middle layer was made from fine sand (size ranged between 0.25 and 0.125 cm) 10 cm depth, and the last layer was consist of coarse sand 0.5–1.0 cm, the rest of upper tube was leaving to place the water sample (Fig. 4), The sand and gravel used in sand filters tubes were previously washed several times using tap water and distilled water (Liu et al., 2000).

For Straw of *H. vulgare* the tube is closed by both ends with glass wool and by medical gauze in bottom, and at the end of the tube, there is a valve used to control the amount of coming out water (Fig. 5).

After the preparation of both kinds of filters, the wastewater (10 L) was poured into the tubes; after that, a layer of cotton 20 cm thick was added to the top of these tubes. Then, the tubes were kept in a storage area for 14 days. The sand used in sand filter tubes was previously washed several times using tap water and distilled water (Liu et al., 2000).

Removal efficiency %

The efficiency of pollutant removal was expressed as a percentage (before and after treatment) as follows: Removal efficiency % = Pp − Pa/Pp,

Pp is the pollutant concentration before treatment, Pa is the pollutant concentration after treatment.

Results and discussion

Physicochemical characteristics of tap water and wastewater before and after treated with the sand filter

The results show Some physical and chemical characteristics of tap water for PH, TDS, TSS, EC, Mg^{2+}, Ca^{2+}, Cl^-, Na^+, Alkalinity, BOD_5, COD, Total hardness, CO_2, NO_3^-, PO_4^{3-}, SO_4^{2-}, Pb^{+2}, Ni^{+2}, Cu^{+2}, Cd^{+2} and SAR were 8.01 ± 0.02, 7.24 ± 0.01, 321 ± 70.50, 1.77 ± 0.01, 100.2 ± 15.01, 60.9 ± 10.01, 226.9 ± 30.01, 186.2 ± 32.09, 66.48 ± 11.89, 1.99 ± 0.03, 5.99 ± 0.07, 2.39 ± 0.02, 1.22 ± 0.02, 0.5 ± 0.001, 108.47 ± 18.07, 0.6 ± 0.04, 0.08 ± 0.001, 0.001 ± 0.0001, 0.02 ± 0.001, 0.00 ± 0.001 and 0.47 ± 0.05. As illustrated in Table 1, which shows the physicochemical characteristics of the raw wastewater before and after treated with the sand filter, the concentrations of Cl^-, PO_4^{3-}, SO_4^{2-} and NO_3^- in the wastewater were higher than those in the tap water. The high concentrations of ions in the wastewater are related to the fact that the wastewater contained agricultural fertilizers, detergents, carbohydrate materials and industrial waste from the city (Hussain and Saati, 2000). The findings of the present work are similar to those reported in previous studies (Al-Ghanemi, 2011; Al-Azaw, 2008; Nageb, 2015; Al-Enazi, 2014). Furthermore, there was a high concentration of heavy metals because of the consumption and discharge of huge amounts of wastewater from industrial factories.

The results show that there was a decrease in the concentration of many of the wastewater components when the sand filter was used (Table 1). The pH of the treated water was 7.9, and the electrical conductivity was 7.54 ds/m. The results also reveal that the sand filter decreased the values of TDS and TSS (2631 mg/l and 699 mg/l, respectively). Many studies focus on TDS because it can be used as an indicator of the salinity and the quality of water (Metcalf and Eddy, 2003).

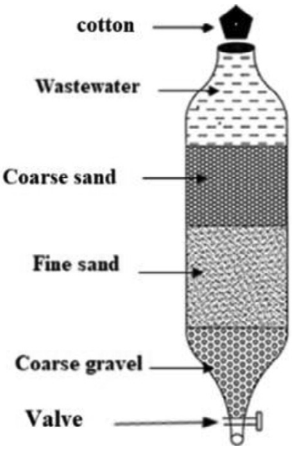

Fig. 4. Sand filters.

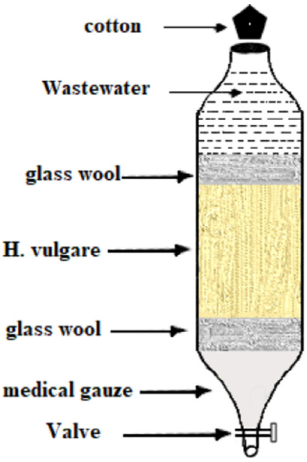

Fig. 5. Straw of *H. vulgare* filters.

Table 1
Physicochemical characteristics of wastewater before and after treated with the sand filter.

	Water type		
P. value	Wastewater treated with sand	Crude wastewater (not treated with sand)	Water characteristics
0.79	7.9 ± 2.89	7.36 ± 2.40	pH
0.00	2631 ± 556.98	3779 ± 230	TDS (mg/l)
0.01	699 ± 200.01	799 ± 302	TSS (mg/l)
1.00	7.54 ± 4.01	8.00 ± 3.01	EC (ds/m^{-1})
0.01	370.71 ± 100.09	469.41 ± 210	Mg^{2+} (mg/l)
0.00	319 ± 120.01	581.1 ± 200	Ca^{2+} (mg/l)
0.00	730.00 ± 320.67	2496.30 ± 540.98	Cl^- (mg/l)
0.00	319.00 ± 101.23	662.85 ± 298.76	Na^+ (mg/l)
0.01	239 ± 97.03	299 ± 99.70	Alkalinity (mg/l)
0.46	12.49 ± 5.90	17 ± 5.09	BOD_5 (mg/l)
0.00	54 ± 30.23	166 ± 89.08	COD (mg/l)
0.00	2299 ± 870.90	3290 ± 560.00	Total hardness (mg/l)
0.52	4.04 ± 2.01	5.40 ± 1.89	CO_2 (mg/l)
0.18	1.19 ± 1.01	3.86 ± 2.01	NO_3^- (µg/l)
0.00	559 ± 210.89	1966 ± 456.08	SO_4^{2-} (µg/l)
0.56	1.1 ± 0.02	1.5 ± 0.89	PO_4^{3-} (µg/l)
1.00	1.8 ± 0.89	2.79 ± 0.99	Pb^{+2} (mg/l)
0.31	0.6 ± 0.04	2.74 ± 1.00	Ni^{+2} (mg/l)
1.00	2.75 ± 0.99	4.08 ± 1.89	Cu^{+2} (mg/l)
NS	0.002 ± 0.001	0.003 ± 0.001	Cd^{+2} (mg/l)
0.52	4.06 ± 2.01	6 ± 3.79	SAR

The results of the present work show the ability of the sand filter to decrease the negative and positive ions, total hardness and total alkalinity. The reason for the decrease in many concentrations is the diverse mechanisms that operate within a sand filter, such as chelation, physicochemical adsorption (Metcalf and Eddy, 2003) and biological growth (Al-Khafaji, 2012).

The present study reveals that the sand filter decreased the concentrations of heavy metals in polluted water (Pb^{+2}: 2.74, Ni^{+2}: 0.74, Cu^{+2}: 4.06 and Cd^{+2}: 0.002 mg/l), and the sodium adsorption ratio (SAR) reached 4.06. The current results show that Pb^{+2} and Ni^{+2} exceeded the level for river maintenance, while Cd^{+2} stayed at the correct level. The other elements were within the levels established by (WHO, 2006).

Removal efficiency of the sand filter in terms of some physical and chemical characteristics of wastewater

The efficiency percentages of the sand filter in removing some chemicals from the wastewater are shown in Fig. 6. The removal efficiency percentages for Mg^{2+}, Ca^{2+}, Cl^-, Na^+, alkalinity, BOD_5, COD, CO_2, NO_3^-, SO_4^{2-}, PO_4^{3-}, SAR were 21.0% ± 3.07, 45.1% ± 12.01 , 70.7% ± 20.01, 51.8% ± 12.12, 0.2% ± 0.01, 26.5% ± 10.09, 67.4% ± 12.98, 25.1% ± 8.7, 69.1% ± 13.80, 71.5% ± 9.08, 26.6% ± 2.90 and 32.3% ± 12.09, respectively. The sand filter decreased some properties of the polluted water. The removal efficiency values for TDS, TSS, EC, and total hardness were 30.3% ± 6.66, 12.5% ± 2.01, 5.7% ± 0.90 and 30.1% ± 8.78, respectively (Fig. 7). In addition, the removal efficiency findings for some physical and chemical characteristics of the primary treated wastewater were compared with those in previous studies. Because of the nature and properties of wastewater, which differ among regions, the efficiency percentage of the sand filter is different. In the present study, the sand filter showed higher efficiencies for phosphate (26.66%) and total hardness (30.12%) than those recorded by (Al-Taan, 2006), which were 16.2 and 27.5%, respectively. Finally, the removal efficiencies for heavy metals are shown in Fig. 8, with values of 35.4% ± 4.89 for Pb^{+2}, 24.0% ± 3.78 for Ni^{+2}, and 33.3% ± 8.90 for Cd^{+2}, which are lower than those recorded by (Holtzmam, 2000) (97.7%, 99.6%, and 97%, respectively). It can be hypothesized that the low percentages of heavy metals in the wastewater are due to the types of industrial factories found in the area, which produce lower amounts of heavy metal discharge.

Physical and chemical characteristics of wastewater treated with sand and other filters

Table 2 shows the characteristics of wastewater treated first with a sand filter and then using filters made of straw of *H. vulgare* and *S. litoralis*. The study involved the measurement of some physical and chemical characteristics of the water treated with these filters Table 3.

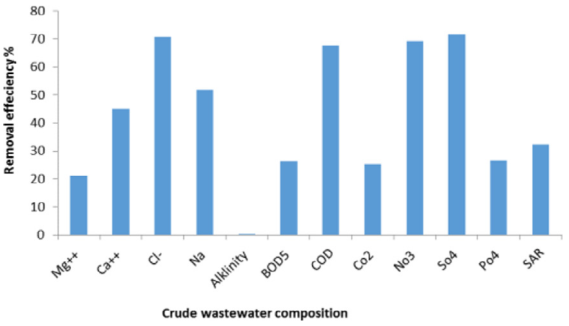

Fig. 6. Percentages of sand removal efficiency for some chemical properties of crude wastewater.

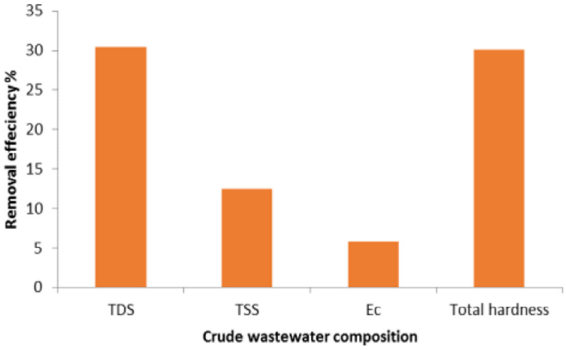

Fig. 7. Percentages of sand removal efficiency for some physical properties of crude wastewater.

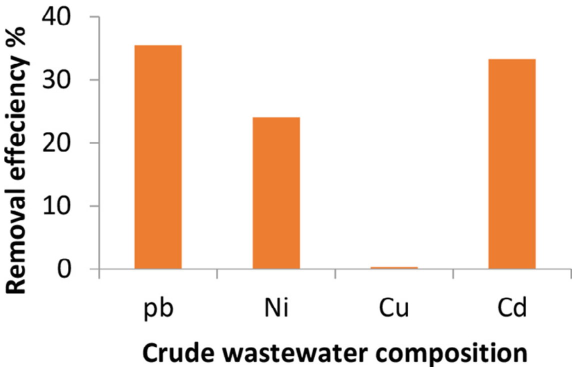

Fig. 8. Percentages of sand removal efficiency for some heavy metals in crude wastewater.

The final removal efficiency was improved after using both the sand filter and plant filters, as demonstrated by the decrease in some values, including EC, TDS, TSS, BOD_5, COD, total hardness, NO_3^-, sulphide, and the sodium adsorption ratio (SAR). Interestingly, there was an increase in the residual sodium ion concentration in the water after treatment with *S. litoralis* plants and straw of *H. vulgare* to a greater concentration than that resulting from treatment with the sand filter only. This could be due to the nature and features of the wastewater used in this study, which was originated from different regions and collection stations. Another reason could be the insertion of some organic matter within the sand particles and the release of some ions. These results could confirm that reductions occur through physicochemical processes or sedimentation (from calcium sulphide) (Al-Imariy, 2006). In some cases, an increase in the pH of water treated with a filter to a greater value than that found in untreated wastewater could be another reason for an increase in ion concentrations. A previous study suggested that most ions dissolve at a low pH, while at a high pH, metals do not dissolve (Imran, 2005). The mechanism used by plants to remove contaminants works by transforming, accumulating and converting them into biomass. Furthermore, there was a small increase in the chloride ion concentration (Table 2), while the magnesium ion increased in association with *H. vulgare*.

The results show that the heavy metal removal efficiency is variable. *H. vulgare* has a higher concentration of Pb^{+2} (1.7 mg/l) than *S. litoralis*. Both of plant filters have an equivalently low residual concentration of Cd^{+2} (0.001 mg/l). There was a decrease in the

Table 2
Physicochemical properties of wastewater treated different filters.

Wastewater type				
Wastewater treated with *S. litoralis*	Wastewater treated with straw of *H. vulgare*	Wastewater treated with sand	Crude wastewater (not treated)	Measurements
8.9 ± 2.27	8.19 ± 3.00	7.9 ± 2.89	7.36 ± 2.40	pH
2120 ± 15.67	2249 ± 456.79	2631 ± 556.98	3779 ± 230	TDS (mg/l)
449 ± 231.03	559 ± 324.01	699 ± 200.01	799 ± 302	TSS (mg/l)
6.72 ± 2.34	7.02 ± 2.33	7.54 ± 4.01	8.00 ± 3.01	EC (ds.m-1)
364.64 ± 189.0	444.86 ± 198.70	370.71 ± 100.09	469.41 ± 210	Mg^{2+} (mg/l)
159 ± 56.78	119 ± 67.89	319 ± 120.01	581.1 ± 200	Ca^{2+} (mg/l)
759.9 ± 435.09	724.19 ± 324.09	730.00 ± 320.67	2496.30 ± 540.98	Cl^{-} (mg/l)
415.14 ± 230.01	439.75 ± 333.90	319.00 ± 101.23	662.85 ± 298.76	Na^{+} (mg/l)
269 ± 20.01	279 ± 123.03	239 ± 97.03	299 ± 99.70	Alkalinity (mg/l)
10.39 ± 5.03	12.4 ± 4.89	12.49 ± 5.90	17 ± 5.09	BOD_5 (mg/l)
35 ± 20.89	45 ± 32.69	54 ± 30.23	166 ± 89.08	COD (mg/l)
1899 ± 723.01	2099 ± 567.89	2299 ± 870.90	3290 ± 560.00	Total Hardness (mg/l)
3.74 ± 1.99	3.64 ± 1.80	4.04 ± 2.01	5.40 ± 1.89	CO_2 (mg/l)
0.07 ± 0.03	1.15 ± 0.20	1.19 ± 1.01	3.86 ± 2.01	NO_3^- (µg/l)
114 ± 98.86	209 ± 99.78	559 ± 210.89	1966 ± 456.08	SO_4^{2-} (µg/l)
0.05 ± 0.02	0.03 ± 0.01	1.1 ± 0.02	1.5 ± 0.89	PO_4^{3-} (µg/l)
1.3 ± 0.99	1.7 ± 0.80	1.8 ± 0.89	2.79 ± 0.99	Pb^{+2} (mg/l)
0.4 ± 0.01	0.3 ± 0.02	0.6 ± 0.04	2.74 ± 1.00	Ni^{+2} (mg/l)
2.77 ± 1.20	2.76 ± 1.01	2.75 ± 0.99	4.08 ± 1.89	Cu^{+2} (mg/l)
0.001 ± 0.0001	0.001 ± 0.0001	0.002 ± 0.001	0.003 ± 0.001	Cd^{+2} (mg/l)
5.44 ± 2.89	5.67 ± 1.89	4.06 ± 2.01	6 ± 3.79	SAR

residual concentration of nickel when using the *H. vulgare* filter. This decrease could be due to the types of filters used in the present study and the particular chemical groups in the plant (*H. vulgare* has carboxyl, phenol and phenol hydroxyl groups). These groups are important in the mechanical removal of heavy metals, as the active group chelates with the heavy metals (Imran, 2005). The *H. vulgare* filter decreased the Pb^{+2} and Cd^{+2} concentrations to safe levels (Ayers and Westcot, 1985). It is obvious that *S. litoralis* plants have a high capacity for pollutant absorption, which has been shown in many studies (Al-Enazi, 2014; Ghoniem et al., 2014; Gober et al., 2015). They have ability to tolerate high concentrations of heavy metals and nutrients and then accumulate them in their tissues (Stottmeister et al., 2003). They decrease the nutrient content in wastewater by taking up nitrogen, phosphate and heavy metals in the water and then decreasing the nutrient content (Katterman and Day, 1989).

Efficiency of filters in decreasing the physical and chemical characteristics of wastewater

The removal efficiency of pollutant was expressed as a percentage (before and after treatment) of the two filters is shown in Fig. 9. *S. litoralis* showed high removal efficiency compared with *H. vulgare* in terms of decreasing TDS, EC, Mg^{2+}, Na^{+}, alkalinity, BOD_5, COD, total hardness, NO_3^-, SO_4^{2-}, and SAR. The removal efficiency percentages were 0.44% ± 0.02, 0.16% ± 0.01, 0.22% ± 0.01, 0.37% 0.02, 0.10% ± 0.02, 0.39% ± 0.03, 0.79% ± 0.04, 0.42% ± 0.05, 0.98% ± 0.08, 0.94% ± 0.09, 0.09% ± 0.02, respectively. This result could have occurred as a result of the ability of plant tissues to absorb nutrients from the water and oxidize them, which causes the size of the pollutants to decrease and increases the surface area available for adsorption on the plant body.

The present study demonstrates the heavy metal removal efficiency of two filters. *S. litoralis* provided a high removal efficiency for Pb^{+2} (0.53% ± 0.04). The removal efficiency for Cd^{+2} was equivalent between *S. litoralis* and *H. vulgare* straw. *H. vulgare* showed a high removal efficiency for polluted water, which reached 0.66%. The removal efficiency of Ni^{+2} by *H. vulgare* was 0.62%.

Statistical analysis

SPSS statistical software (version 24) was used to calculate Inter-Item Correlation, which quantifies how much consistency there is between the items in a scale (how well do the items hang together). Table 4 shows clearly that there are associations between all of the items, where different items in a scale are consistently measuring the construct of interest. First, the correlation between pH and TDS was -0.769 indicating there is no significant correlation between them, and the correlation between pH and TSS was -0.638 denoting there is no significant correlation between them, and so on. On the other hand, the correlation between pH and NO_3^- was -0.848, which means that there is a significant correlation at the 0.05 level, and the correlation between TSS and BOD_5 was 0.918 indicating significance at the 0.01 level.

Conclusion

The results of the present work prove the ability of the investigated filters in terms of wastewater treatment and the removal of pollutants. The TDS, TSS and EC decreased in association with the studied filters. In addition, reductions in the concentrations of both positive and negative ions, including Cl^-, PO_4^{3-}, SO_4^{2-}, Na^+, NO_3^-, Mg^{2+} and Ca^{2+}, were observed, with values of 730.00 mg/l, 1.1 µg/l, 559 µg/l, 319.00 mg/l, 1.19 µg/l, 370.71 mg/l and 319 mg/l, respectively. Moreover, the results show that the removal efficiency both decreased and increased. A higher removal efficiency was found in association with the plant *S. litoralis* compared with *H. vulgare.*

Main finding

Removal efficiency was improved after using a sand filter and plant filters. The decrease of some values includes heavy metals, EC, TDS, TSS, BOD_5, COD, Total hardness, NO_3^-, sulfide as well as adsorption sodium (SAR) after treatment with *Schoenoplectus litoralis* and *Hordeum vulgare.*

Table 3

Inter-Item Correlation Matrix.

Inter-Item Correlation Matrix

	pH	TDS (mg/l)	TSS (mg/l)	EC (ds/ m⁻	Mg^{2+} (mg/l)	Ca^{2+} (mg/l)	Cl^- (mg/l)	Na+ (mg/l)	Alkalinity (mg/l)	BOD_5 (mg/l)	COD (mg/l)	Total Hardness	CO_2 (mg/l)	NO_3^- (µg/l)	SO_4^{2-} (µg/l)	PO_4^{3-} (µg/l)	Pb^{+2} (mg/l)	Ni^{+2} (mg/l)	Cu^{+2} (mg/l)	Cd^{+2} (mg/l)	SAR
pH	1.000																				
TDS (mg/l)	−0.769	1.0																			
TSS (mg/l)	−0.638	0.953*	1.0																		
EC ($ds.m^{-1}$)	−0.126	0.713	0.837*	1.0																	
Mg^{2+} (mg/l)	−0.153	0.732	0.798	0.965**	1.0																
Ca^{2+} (mg/l)	−0.697	0.816*	0.896*	0.640	0.596	1.0															
Cl^- (mg/l)	−0.619	0.759	0.799	0.612	0.658	0.929**	1.0														
Na^+ (mg/l)	−0.365	0.707	0.753	0.762	0.846*	0.778	0.925**	1.0													
Alkalinity (mg/l)	−0.012	0.619	0.729	0.966**	0.984**	0.555	0.622	0.831*	1.0												
BOD_5 (mg/l)	−0.351	0.839*	0.918**	0.960**	0.964**	0.786	0.795	0.888*	0.936**	1.0											
COD (mg/l)	−0.685	0.829*	0.858*	0.639	0.674	0.953**	0.992**	0.904**	0.622	0.820*	1.0										
Total Hardness	−0.344	0.823*	0.920**	0.958**	0.949**	0.812*	0.811*	0.889*	0.930**	0.997**	0.833*	1.0									
CO_2 (mg/l)	−0.324	0.789	0.906**	0.948**	0.930**	0.832*	0.830*	0.897*	0.922**	0.987*	0.844*	0.996**	1.0								
NO_3^- (µg/l)	−0.848*	0.866*	0.818*	0.484	0.544	0.903**	0.935**	0.798	0.451	0.705	0.961**	0.707	0.704	1.0							
SO_4^{2-} (µg/l)	−0.786	0.802*	0.817*	0.501	0.520	0.961**	0.965**	0.802*	0.457	0.706	0.979**	0.724	0.739	0.975**	1.0						
PO_4^{3-} (µg/l)	−0.868*	0.680	0.698	0.234	0.148	0.849*	0.667	0.361	0.070	0.401	0.721	0.431	0.445	0.784	0.833*	1.0					
Pb^{+2} (mg/l)	−0.474	0.885*	0.974**	0.908**	0.834*	0.819*	0.689	0.688	0.788	0.926**	0.750	0.930**	0.916**	0.671	0.686	0.590	1.0				
Ni^{+2} (mg/l)	−0.705	0.787	0.833*	0.577	0.588	0.974**	0.984**	0.852*	0.543	0.761	0.990**	0.783	0.803*	0.952**	0.992**	0.788	0.722	1.0			
Cu^{+2} (mg/l)	−0.268	0.776	0.911**	0.972**	0.895*	0.749	0.648	0.714	0.885*	0.947**	0.691	0.954**	0.948**	0.555	0.591	0.430	0.972**	0.654	1.0		
Cd^{+2} (mg/l)	−0.604	0.880*	0.971**	0.810*	0.761	0.965**	0.885*	0.812*	0.720	0.906**	0.921**	0.923**	0.930**	0.846*	0.888*	0.742	0.936**	0.916**	0.892*	1.0	
SAR	0.034	0.566	0.666	0.928**	0.972**	0.509	0.619	0.848*	0.993**	07**	0.607	0.898*	0.892*	0.433	0.434	0.000	0.717	0.522	0.825*	0.667	1.0

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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